LET painting through proton monoenergetic arc therapy (PMAT) to enhance RBE

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INTRODUCTION AND AIM

We present **Proton Monoenergetic Arc Therapy (PMAT)**, a new delivery technique in proton radiotherapy based in the concept of monoenergetic partial arcs. Although this technique contains the typical dosimetric characteristics of arc radiotherapy; its justification is based on that only placing Bragg peaks within the tumor increases the LET in that structure and, potentially, the biological effectiveness. This increase in the tumor is also consistently accompanied by a decrease in the surrounding OARs without any specific LET constraint during the inverse optimization. Hence, PMAT emerges as an interesting arcing technique, not only from the dosimetric point of view, but also because of its potential biological enhancement.

METHOD

A PMAT complete arc is composed of monoenergetic sub-arcs, whose length, position and energy are selected by an algorithm that computes the water-equivalent depths (WED) of the target from each angular control point, separated by 1 deg in this work [1]. This algorithm recursively selects the longest consecutive sub-arc with target points within the interval from 50% to 60% of the difference between minimum and maximum WED from each control point. An in-house inverse optimization is used together with dose constraints for target and organs at risk (OARs) to produce clinically acceptable plans. We show here the dosimetric performance of PMAT applied to various sites, such as prostate, brain or H&N.
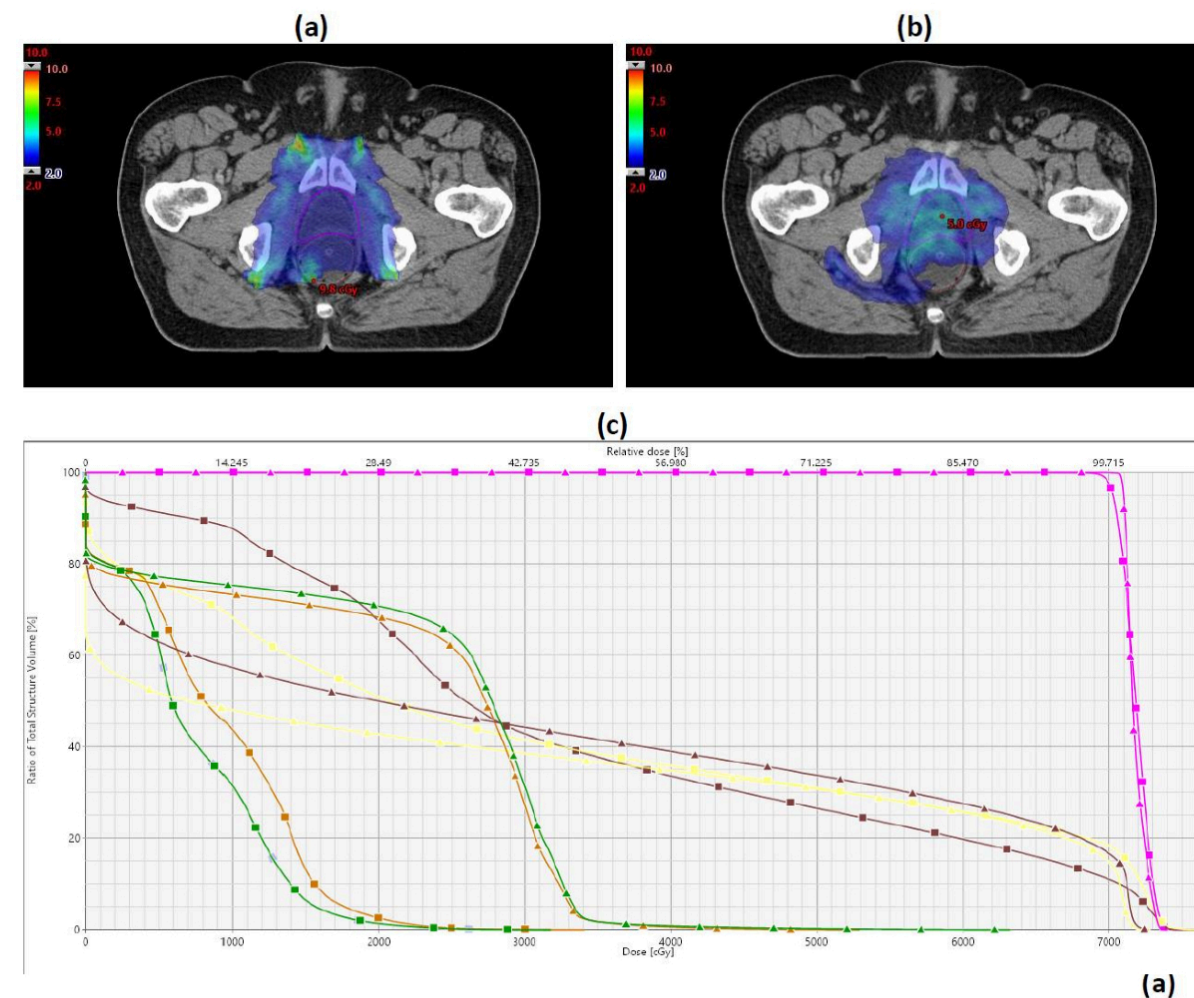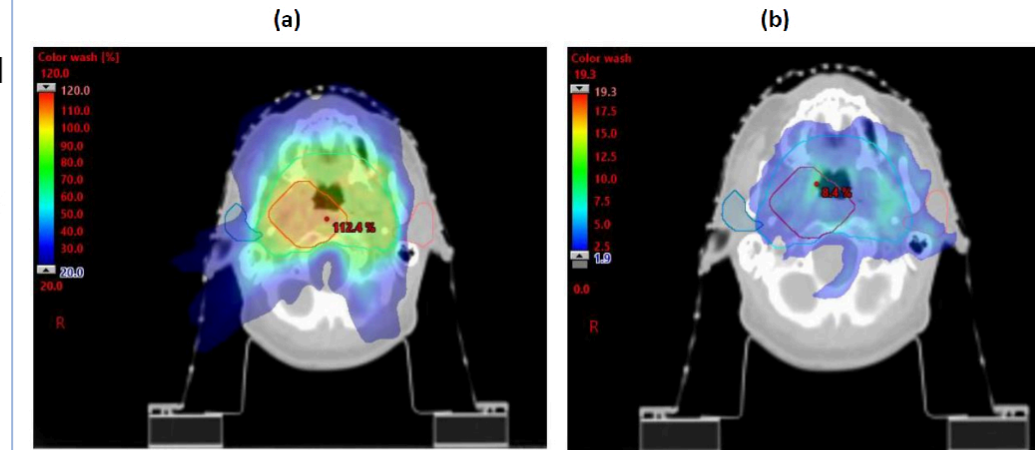
RESULTS

Figure 1. Prostate case. LETd distributions obtained with **(a)** a two-lateral beams PBS plan and **(b)** PMAT plan for the considered prostate case. Color map expresses LETd in keV/μm. DVHs for the clinical prostate case comparing dose to the CTV (purple); rectum (brown); bladder (yellow); right femoral head (orange) and left femoral head (green) with PBS (triangles) and PMAT (squares).

Figure 3. Head and Neck case. (a) Dose distribution, and (b) LETd distribution (color scale indicates keV/μm). Red contour represents one PTV with prescription equal to 100% of dose shown in color wash (1.8 Gy/fx), blue sky contour depicts another PTV with prescription equal to 85% of dose shown in color wash (1.5 Gy/fx). Green and orange contours represent right and left parotids, respectively.

PMAT produces comparable dose distributions to the CTV to IMPT plans for the three considered cases/sites. As expected, the resulting distributions for LETd contain higher values in the CTVs than in the rest of considered structures. RBE calculations according to different models show a clear enhance of biological effectiveness for PMAT plans with respect to IMPT.
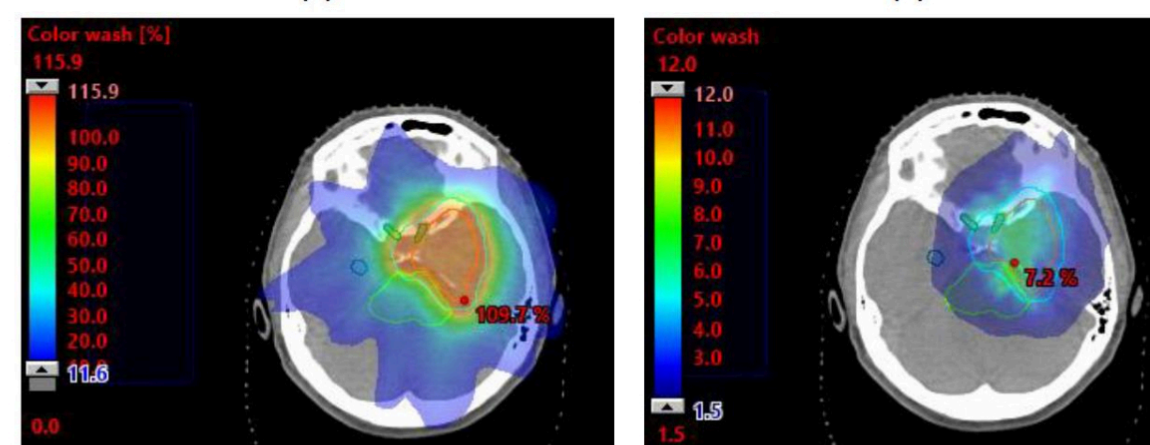
Figure 2. Brain case. (a) Dose distribution, and (b) LETd distribution (color scale indicates keV/μm). Orange contour represents CTV, blue sky contour depicts PTV and green contour represents brainstem.

CONCLUSIONS

PMAT naturally increases LETd within the target, leading to a potential enhancement of the biological dose and, subsequently, of the tumor control probability (TCP). This opens the door to possible dose de-escalation towards a lower NTCP while maintaining the same biological effectiveness of the plan due to a redistribution of higher LET to the high-dose volume of the plan. The simultaneous decrease of LETd in OARs may also enable dose escalation to increase TCP while controlling NTCP.

ACKNOWLEDGEMENTS

REFERENCES

[1] Bertolet, A., & Carabe, A. (2020). Proton Monoenergetic Arc Therapy (PMAT) to enhance LETd within the target. Physics in Medicine and Biology. https://doi.org/10.1088/1361-6560/ab9455

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